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Some Frontiers of the Lighting Art*

By WARD HARRISON†

Introduction

First, on behalf of my colleagues in the American I.E.S., and, second, on behalf of myself, I acknowledge the high honour of your invitation to address your annual meeting to-day. May I say also that it is a very great pleasure to be here and to feel so at home among the many of you whom I have counted as my friends over so long a span of years. I am moved to ask, "Is there any field of endeavour in which there is a closer bond between the citizens of our two great nations than in the field of light production and illuminating engineering?" Using the word "profit" in its best sense, we have both profited thereby; in the "we" I would include the profession, the industry, and the public. To cite one example: Even in the interval since the International Commission meeting here in 1931, we have become deeply in your debt for your invaluable contributions to the development of the fluorescent lamp of to-day. This indebtedness is not lessened by the very recent decision of leading American manufacturers to adopt your special types of phosphors for their standard fluorescent lamp production.

I doubt, too, if you realise with what interest your publications, the *Transactions* of the Illuminating Engineering Society and *Light and Lighting*, are read each month in the U.S.A. The fact that they are just now less voluminous than the corresponding issues of our own journals is by no means an unmitigated privation. In my own case, for instance, I can find time only to skim our periodicals, but I do read yours through. Of course, as bystanders always will, some of us look with tolerance tinged with something akin to superiority at your efforts to overturn such a seemingly simple, tried and serviceable term as "footcandle." I note that you have now passed through the stages of the cumbersome "lumens per square foot" to "l.s.f.," and most recently to "luf." How will the layman know whether the plural is luf or lufs? Seriously, would not more be accomplished for the progress of the lighting art if the effort needed to effect such a change were instead directed toward bringing about a familiarity with brightness units and their relatively greater significance in seeing?

On the other hand, many idiosyncracies of our own, no doubt, are even more apparent to you. As you have seen from our publications we are giving serious thought now to such terms as "delos," "helios," "logance," and "pharosage"—all of which may or may not succeed in attaining general acceptance over the long term.

Frontiers of the Lighting Art

And now to approach more closely to the announced subject of this address "Some Frontiers of the Lighting Art." To say that to-day we have no lack of challenging frontiers is a considerable understatement; more truthfully, we are burdened with a superfluity of them, for example:—

(i) As to light sources, it is scarcely necessary to remind you that there is

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* Presented at a meeting of the Society held on June 17th, 1948.

† Director of Engineering, Lamp Department of General Electric Co., Nela Park, Cleveland, Ohio, U.S.A.

still at least theoretical opportunity for a gain of three or four times in lumens per watt without departing materially from white light.

(ii) The extensive and pleasing application of coloured light is still an almost unexplored field.

(iii) Our current methods of lighting streets and heavily travelled highways involve the use of luminaires much too small and too widely spaced to give really effective illumination such as we know it indoors.

(iv) We are not agreed as to what footcandles are desirable and necessary for various indoor tasks, as in offices, factories and schools.

(v) We are not agreed as to what brightness patterns, including specular reflections, are desirable or permissible within the visual field when the eyes are directed somewhat downward toward such tasks.

(vi) We have no generally accepted method of predetermining what degree of visual comfort will be experienced when the eyes are raised from the work.

Any of you could continue to amplify such a list of lighting frontiers, but it is unnecessary to labour the point, and to-day I would like to concentrate your thoughts on the last three that have been mentioned: (1) Desirable levels of illumination, (2) suitable brightness distribution surrounding the visual task, and (3) ocular comfort when the eyes are raised from the work.

These three factors determine in great measure the satisfaction which will be derived from any utilitarian lighting system. I prefer to approach them from the viewpoint of an engineer rather than that of a research scientist—which I am not. Much that I have to offer, you may not deem pertinent, and with some of it you may disagree. However, in considering those statements to which you do not subscribe it might be well to keep in mind that merry Continental quip—or was it of British origin?—that "Among Americans ignorance is never accepted as an adequate excuse for silence"—and you did invite me here to speak!

(1) Desirable Levels of Illumination

Extensive scientific investigation has already been carried on in this field, and here it would be appropriate to mention in particular the work of Lythgoe, Weston, and Luckiesh. However, there is almost no contribution which has not been challenged by someone either from the standpoint of the premises on which it is based, or on the method by which the experimental results are applied to practical problems. Dr. M. E. Bitterman, of the Department of Psychology, Cornell University, Ithaca, N.Y., has recently offered a paper to our Illuminating Engineering Society in which he summarises the present status. This will appear in our Transactions shortly, and I believe that you will find much of interest both in the paper and in the discussion which it will engender.

Dr. Bitterman discusses the various investigations that have been made and points out their elements of strength and their weaknesses. He calls attention to the pitfalls of attempting to evaluate the relative merits of different illumination levels simply by measuring outputs attained under them. He emphasises that the evaluation of lighting is essentially a problem in human efficiency which involves input measured in physiological cost, as well as output measured in terms of useful work. It is recognised that it is exceedingly difficult to measure the cost of sedentary activities and that is why there is such a pressing need for increased fundamental research in this area. No one says that the data thus far taken are incorrect but only that they are not altogether conclusive.

Meanwhile, as an engineer, I am not too disturbed because we cannot set down scientifically and mathematically determined figures for the exact

illumination to be specified for a hundred or more tasks. It is hardly necessary to remind you that it is only in connection with our relatively less important problems that we have such precise information to guide us. Really major decisions, such as a medical diagnosis, the choice of a career, the proper location for a manufacturing establishment, and even the wage scale for labour, are all arrived at necessarily as the result of considered judgment, or judgment sometimes not too well considered. In none of these instances can we open a book and find a mathematical formula from which the answer can be accurately calculated. Of course, no one would argue against transferring to the realm of certainty just as many of our partially solved illumination problems as we can. We should not feel an undue sense of frustration and embarrassment if they are not all in that category. Actually we have made a good start toward a number of them, including those which involve footcandle recommendations.

Suppose for a moment we look at the matter simply from the standpoint of practical experience. Between 1940 and 1942 many large war plants were constructed in the United States. In general the estimation of their necessary size was based on experience in existing plants which had been converted to war uses. In nearly every instance the output of the new factories materially exceeded the estimates. Why? By and large they could be differentiated from their predecessors only in three respects: (1) Better layout of work, (2) Better environment, that is, better ventilation, minimum noise level, better temperature control, and sometimes air-conditioning, (3) Better illumination, usually 40 footcandles or more. An overriding factor was, of course, the universal interest in winning the war. This, however, affected the employees of both old and new factories alike.

To some plant managements the high standard of illumination was regarded merely as an experiment, and in the belief that ultimately the Government would pay the bill anyway. As time went on, however, an opportunity was afforded of obtaining actual appraisals by the managements of the value of the lighting. Many of the new plants were duplicated, often in other localities as the demand for munitions was stepped up. Before the end of the war we were able to compile data on some 22 large plants that had been so duplicated. In 21 of them the illumination level of the original plant was either equalled or surpassed, and in the case of the one where the lighting was reduced the change was a minor one, owing to practical limitations of outlet spacing and the choice of a different illuminant. Of course, such evidence falls far short of *proof* that 40 footcandles was one of the material factors which resulted in high output in war plants, but at least it becomes "suspect."

Far more convincing was our experience as the war was drawing to a close and the thoughts of manufacturing executives were turning to peace-time production. Numerous representatives of the large manufacturers in our country came to us and said, "Now we are going back to the normal operation of our original factories; we want to light them the way our war plants were lighted. We are convinced that it pays." And why shouldn't it pay? Between the beginning of World War I and World War II progress in the efficiency of light sources was such that more than five times the illumination became obtainable for the same consumption of electricity. The cost of electricity during the same period went down in a ratio of approximately 2 to 1. Hence 40 footcandles may now be obtained for the same energy-cost as 4 footcandles in 1914. Meanwhile, in most communities, labour rates and nearly every other item of cost has more than doubled, so that even with the higher investment charges for fluorescent lighting 40 footcandles represents a smaller proportion of a company's operating

cost to-day than 4 footcandles did 30 years ago. In view of these facts, whenever coal supplies and funds are adequate, is it not advisable, and much safer from the standpoint of conserving human resources, to err on the side of installing lighting generously rather than to choose the very least that may serve on a "make-do" basis?

(2) Brightness Distribution Surrounding the Visual Task, with Emphasis on Reflected Glare

A part of the discussion which follows may apply to manufacturing occupations as well, but what I have in mind primarily may be classed as paper work, such as is found in offices, drafting rooms, and schools. I shall make the assumption also that when one's eyes are concentrated on a visual task the head is inclined sufficiently so that overhead light sources are not in one's field of view. In the interest of simplifying the problem, such an assumption may be permissible even if not strictly true, especially since the glare effect of overhead light sources will be treated rather fully in subsequent paragraphs.

In offices the visual tasks in which we are generally interested embody seeing relatively small detail against its immediate background. What is the effect of other surfaces in one's general visual field whilst the eyes are fixed primarily on the work? This visual field may be taken to include perhaps 30 deg. to 40 deg. in all directions from the central line of sight. All surfaces, even though not consciously being looked at, register on the retina somewhat in proportion to their size, to their location, their brightness in comparison with the brightness of the work to which the eyes are adapted, and the contrast between the mass in question and its own surroundings. The eyes are constantly moving back and forth across the work, and the images of these extraneous objects, blurred and vague though they may be, likewise move back and forth across the retina. We become so accustomed to our work environment that our minds pay little attention to these extraneous images, but the eyes are working at it every minute. Many who have studied the subject, by the sheer weight of their collective opinion and experience, have given us a widely accepted prescription for the work area, namely: nothing in that area should be appreciably brighter than the visual task, nor less than one-third as bright.

In practical terms, adhering to this three-to-one brightness ratio means that where work involves white paper, the reflection factor of desk tops should be brought up to about 30 per cent., that floors should be as light as possible, vertical surfaces or furniture should have their dark finishes lightened, stacks of dark files and transfer cases should not enclose the work space, and nearby wall areas should be of a light colour. The increasing popularity of linoleum desk tops in light colour and natural colour finishes for wood marks a distinct advance in appreciation of the importance of comfort in the work environment.

Too-bright areas in the visual field are often the result of reflected glare, the more or less well defined images of bright light sources seen in plate glass, in shiny varnished desk tops, in bright surfaces on drafting implements and office machines, and in varnished woodwork, especially in schools. W. G. Darley (1) has pointed out in a recent paper that in binocular vision the two reflected images of a bright source do not fall at the same point on the work surface, and this fact gives rise to some serious problems in focusing.

I would like to emphasise too that individual bright light sources are not

(1) "An Analysis of Reflected Glare," *Illuminating Engineering*, Vol. XLII, page 85, January, 1948.

the only causes of reflected glare. Even with indirect lighting and moderately calendered paper reflected glare causes a slight film or haze that one is never quite fully aware of until he sees it removed. To illustrate this, one may take a position near the side wall facing the centre of an indirectly-lighted room, and hold out horizontally a pamphlet (preferably one with a coloured cover) then turn quickly and face the side wall, revolving the pamphlet with him as shown in Fig. 1, a and b. It will immediately become apparent how much deeper the colour seems on the cover and how much more clearly the type stands out in the second position; there is now no specular reflection towards

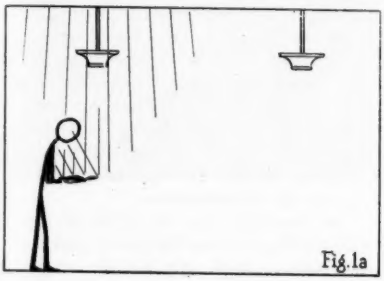


Fig.1a

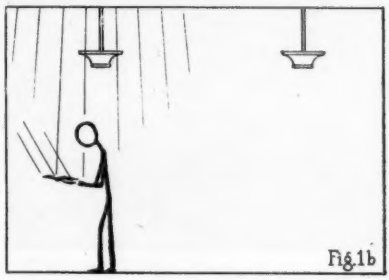


Fig.1b

the eyes—the film has been removed. In the author's opinion a slight amount of such film may nullify the effect of a substantial increase in illumination—"We see through a glass, darkly."

I am under the impression, not too well substantiated, that one's consciousness of reflected glare becomes more pronounced as illumination levels go up. Daylighting is characteristically side lighting, and perhaps this gives us an inkling of why daylight illumination in an office is welcomed in almost any quantity short of direct sunlight, whereas we have not had too much success with artificial lighting systems of comparable footcandle values. In daylight, if desks are placed at right-angles to the windows as they usually are, most of the specular reflection goes off harmlessly past the worker (Fig. 2). With high levels of artificial illumination the light characteristically comes from

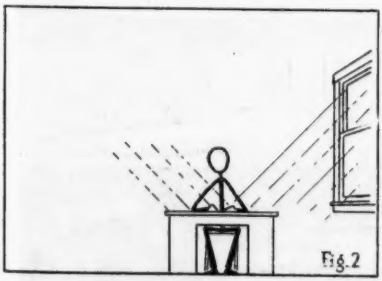


Fig.2

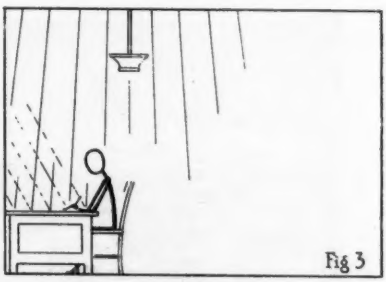


Fig 3

above, and the only way to escape specular reflection is to place one's desk against the wall (Fig. 3). This obviously is impracticable for most of the occupants of a large general office.

Some may say "Why worry about specular reflection? Actually it is sometimes helpful in identifying three-dimensional objects and also irregularities in plane surfaces. If it bothers you at your desk, why not pick up your

Fig. 4. Early louverall (Nela Park, 1939).

reading matter and tilt it until the specular goes off in another direction?" This latter is well enough to propose but oftentimes it is impracticable; moreover, having to resort to it is in itself an admission that the lighting system is considerably short of perfection. A comparison of desk lamps with and without polaroid screens is as convincing a demonstration as one could wish of the superiority of illumination free from specular reflection. Such reflection from papers and other objects on one's desk or drafting board is always annoying; and where glossy ink or a hard pencil has been employed, visibility may be materially reduced by its presence.

In America the so-called louverall ceiling (Fig. 4) has recently come into prominence and apparently only its relatively high cost will keep it from becoming the standard for office illumination, especially for high-level systems where continuous rows of fluorescent lamps are employed. With a well-designed louverall, which should shield the light sources to fully 45 deg., the brightness of the surface from which the light seems to come is for the first time actually less than that of the work which it illuminates. In fact, the visible

Fig. 5. Louverall ceiling lighting in the main United Nations meeting room at Lake Success.

Fig. 6a.

Fig. 6b.

ceiling is about one-sixth as bright as in indirect lighting; it is an effect which must be experienced to be appreciated The main United Nations meeting room at Lake Success (Fig. 5) is lighted in this manner and is the one area there whose lighting has not been severely criticised, especially by delegates from abroad.

From the standpoint of reflected glare the louverall is no improvement over many other luminaires and at first thought, it would seem considerably inferior to indirect lighting because the lamps shine directly on the work. If the rows of lamps are far apart each of them will give rise to a distinct streak of brightness on a sheet of calendered paper on one's desk. However, unless the paper has an extremely high polish, like that of some photographic prints, the result in any lighting installation is not true specular reflection but is partly spread reflection and the streak is considerably broader than a true image of the lamp would be in a mirror placed at the same spot (Fig. 6a). As the rows of fluorescent lamps are brought closer together the streaks tend to merge

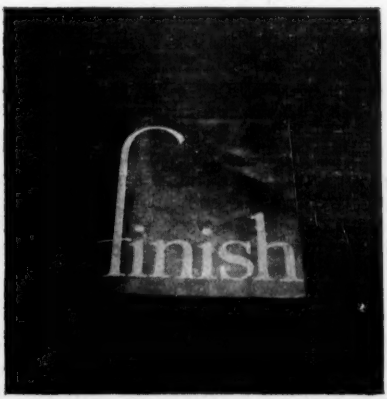


Fig. 7a.

Fig. 7b.

until finally the spread reflection is almost uniform over the entire surface (Fig. 6b). The point at which this occurs depends of course upon the specularity of the task as well as the spacing of the light sources. When the condition is reached, however, the reflected glare is comparable to that experienced under totally indirect lighting (Fig. 7a). For comparison, Fig. 7b shows the magazine photographed from the reverse direction with no reflections towards the camera lens.

Just recently we have attempted to eliminate all specular reflection in the direction of the eyes by means of a modified louverall. The louvres perpendicular to the windows are kept vertical as before, but the louvres parallel to the windows are inclined at an angle of 45 deg. These louvres are sufficiently wide to ensure that no light can come down vertically between them and with this arrangement (Fig. 8) all of the specular reflection passes off to one side,

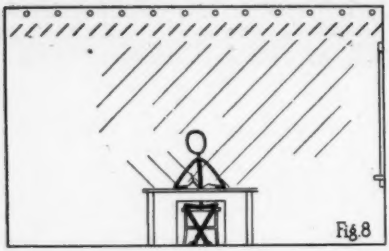


Fig. 8

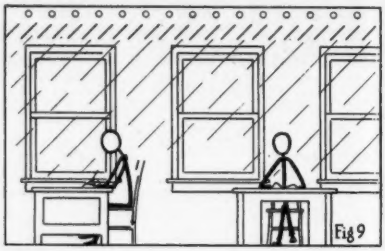


Fig. 9

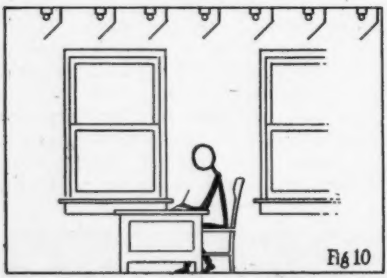


Fig. 10

much as in daylight If one sits with one's back to the window the specular reflection will be directly away from one.

The results will be similar if the louvres perpendicular to the windows are inclined and the others are vertical. A system of this kind is particularly applicable in a large general office with windows on the long side and with the the desks facing either end wall or the inner wall (Fig. 9.)

Such an installation has been made in one of our offices at Nela Park and the results seem distinctly superior. It is our belief that with this system there is almost no top limit to acceptable levels of artificial illumination.

A very simple and inexpensive application of the same principle consists in installing continuous rows of bare fluorescent lamps near the ceiling and placing a deep diagonal baffle immediately behind each row as shown in Fig 10. Some installations of this type have been used with considerable success where all the occupants of the office face in the same direction. The use of low-brightness lamps is indicated.

(3) Comfort when the Eyes are Raised from the Work

For one reason or another a considerable portion of one's time in an office is spent with one's line of sight at or near the horizontal. It may be to relax briefly, or to think, or to converse with a business associate. It is important that the lighting should be comfortable under these circumstances, particularly

as in most cases the quality of a lighting system is judged principally by this criterion. Excessive brightness of light sources was usually assumed to be the cause of any discomfort, but more and more it has come to be recognised that area of source is also important—as a simple demonstration may serve to show. Even indirect lighting may be objectionable if the expanse of ceiling is large enough and the illumination is at a high level. For example, our experience in the United States indicates that for a reasonably spacious general office the ceiling brightness necessary to provide about 40 footcandles of indirect lighting represents the upper limit for comfort. In the case of enclosing globes for incandescent lamps or bare fluorescent lamps the limit is reached at much lower levels. In some instances going higher actually creates a negative impression which may quite overshadow one's appreciation of the value of the increased illumination. In fact, comfort may seem to be improved when half of the luminaires are turned off and the user may erroneously conclude that he had too much light when in reality he was just inescapably conscious of the light source or sources.

It may be argued in any given case that a poor choice of fittings was responsible, but it happens that a luminaire which may be found entirely satisfactory in one office may prove quite the reverse in another room in different conditions. After an installation has been completed there is usually good agreement among engineers as to whether it is satisfactory as regards absence of direct glare, but in advance there is often the widest diversity in their predictions. In the few minutes remaining I will attempt to outline very briefly a method by which I am hopeful that the satisfactoriness of a given lighting installation from the glare standpoint may be reasonably evaluated in advance. For a more detailed discussion of the basis of this system reference is made to papers already published in the American I.E.S. Transactions (2).

It is generally accepted that the following factors are the five which have an influence on the sensation of direct glare:—

(a) Brightness of light sources.
(b) Apparent area of light sources.
(c) Height of the light sources above eye level.
(d) Position of sources in the field of view (distance and angular displacement).
(e) Brightness of immediate background of luminaires and the general surround.

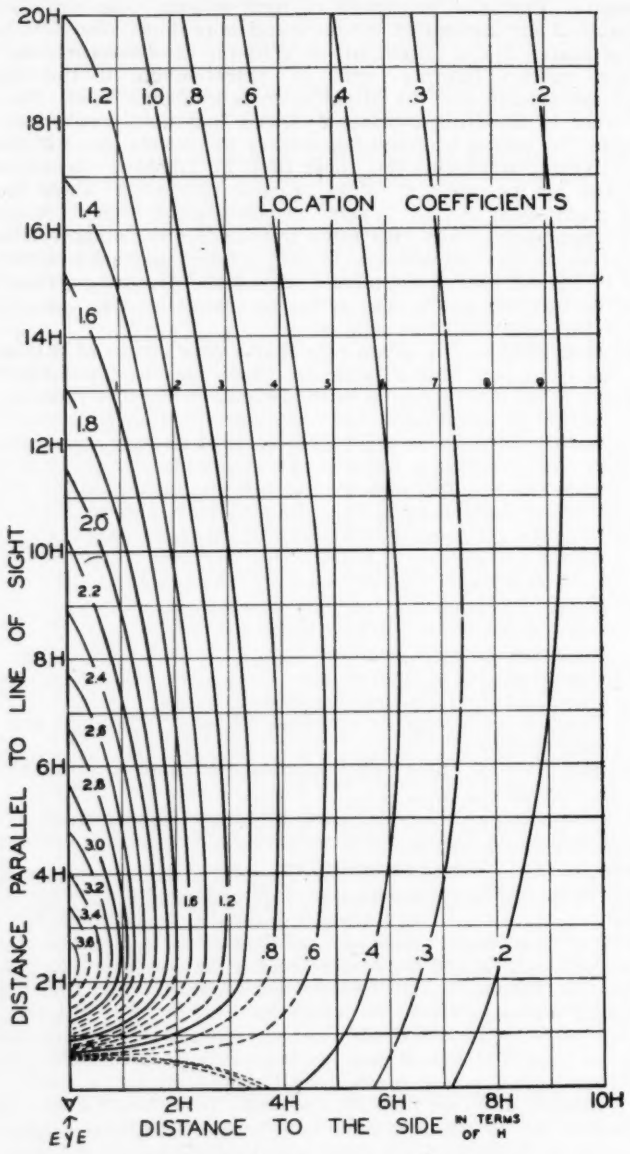
Based on incomplete laboratory data which are supplemented by the considerable experience of qualified engineers, these five factors have been combined in an empirical formula as follows:—

$$\text{Discomfort Glare Factor} = \frac{\text{Apparent Source Area} \times (\text{Brightness})^2 \times \text{Location Coefficient}}{(\text{Height above Eye Level})^2 \times \text{Surround Factor}}$$

The unit of brightness is taken as 1,000 footlamberts; the unit of projected area is 1 square inch; height above eye level is measured in feet; the location coefficient is found from Fig. 11; the surround factor is found from Fig. 12.

Computing the glare factor for a lighting system in accordance with the formula is admittedly laborious, due in considerable part to the difficulty of calculating the projected area of each of the luminaires when viewed at various angles. However, it is not so much more time-consuming to obtain the glare factor for a number of rooms than for one single room, and Tables I to X illustrate such data for several luminaires in rooms of various dimensions. It should be kept in mind that the degree of discomfort does not vary directly

(2) Vol. XL, No. 8, Sept., 1945, p. 525; Vol. XLII, No. 2, Feb., 1947, p. 153.


LOCATION COEFFICIENTS
1.2
1.0
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1.8
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2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
20H
18H
16H
14H
12H
10H
8H
6H
4H
2H
DISTANCE PARALLEL TO LINE OF SIGHT
EYE
2H
4H
6H
8H
10H
DISTANCE TO THE SIDE IN TERMS OF H

Fig. 11.

General Surround Brightness, Foot-lamberts	Brightness of Immediate Background of Light Source—Footlamberts													
	.01	0.1	1.0	2.0	5.0	10	20	50	75	100	150	200	500	1000
0.1	.03	.06	.12	.14	.17	.19	.21	.23	.24	.25	.26	.27	.29	.31
0.2	.04	.08	.18	.21	.25	.28	.31	.35	.37	.38	.40	.42	.46	.49
0.5	.06	.10	.21	.26	.33	.38	.43	.49	.52	.54	.57	.59	.66	.71
1.0	.08	.12	.25	.32	.42	.50	.58	.67	.72	.75	.79	.82	.92	1.0
1.5	.10	.15	.26	.36	.49	.58	.68	.81	.86	.91	.96	1.0	1.1	1.2
2.0	.12	.16	.29	.38	.53	.65	.76	.92	.98	1.0	1.1	1.1	1.3	1.4
3.0	.14	.20	.33	.42	.59	.74	.89	1.1	1.2	1.2	1.3	1.4	1.6	1.7
5.0	.18	.24	.39	.47	.66	.86	1.1	1.3	1.4	1.5	1.6	1.7	2.0	2.2
7.5	.22	.29	.45	.54	.72	.94	1.2	1.5	1.7	1.8	1.9	2.0	2.4	2.6
10	.25	.33	.50	.59	.77	1.0	1.3	1.7	1.9	2.0	2.2	2.3	2.7	3.0
15	—	.40	.59	.68	.87	1.1	1.4	2.0	2.2	2.3	2.6	2.7	3.2	3.6
20	—	.46	.66	.76	.95	1.2	1.5	2.1	2.4	2.6	2.8	3.0	3.6	4.1
30	—	.56	.78	.89	1.1	1.3	1.6	2.4	2.7	2.9	3.3	3.5	4.3	4.9
50	—	—	1.0	1.1	1.3	1.5	1.9	2.6	3.1	3.4	3.9	4.2	5.2	6.0
75	—	—	1.2	1.3	1.5	1.8	2.1	2.8	3.4	3.8	4.4	4.8	6.1	7.1
100	—	—	1.3	1.5	1.7	2.0	2.4	3.1	3.6	4.0	4.7	5.2	6.8	8.0
200	—	—	—	2.0	2.3	2.6	3.0	3.8	4.2	4.6	5.4	6.0	8.4	10.3
500	—	—	—	—	3.5	3.9	4.4	5.2	5.7	6.2	6.9	7.5	10.4	13.6
1000	—	—	—	—	—	5.3	5.9	7.0	7.5	8.0	8.8	9.4	12.3	16.0

Fig. 12.

with the numerical value of the glare factor; that is, where the glare factor doubles this does not mean that discomfort is doubled, but only that, as the formula shows, the source area is relatively twice as great. The relative significance of the numbers becomes apparent from subjective appraisals from which one can establish ranges suitable for different types of interiors or activities. Experience indicates that where the glare factor is less than 15, conditions as to direct glare will be satisfactory for offices, drafting rooms, schools, etc. A glare factor considerably higher than this—even 100 or more—may prove appropriate for retail shops, railway stations, and many other locations.

Fig. 13 gives a comparison of calculated glare factors and the averaged subjective appraisal of seven engineers as to the relative freedom from discomfort in ten lighting installations. It will be noted that in nine of the ten cases the installations were rated in the same sequence by both methods of appraisal.

There is not time nor is this the place to go into further ramifications of the glare-factor concept. However, between our scheduled meetings here I would be pleased indeed to discuss the subject with any of those who are interested, in as much detail as you may wish.

Recapitulation

And now, to summarise, may I repeat—(1) Desirable footcandle levels, (2) Suitable brightness distribution surrounding the task, including specular reflection, (3) Freedom from direct glare when the eyes are raised from the work. These three are perhaps the most important considerations in illuminating engineering, and they are still our frontiers. I realise I have been able to

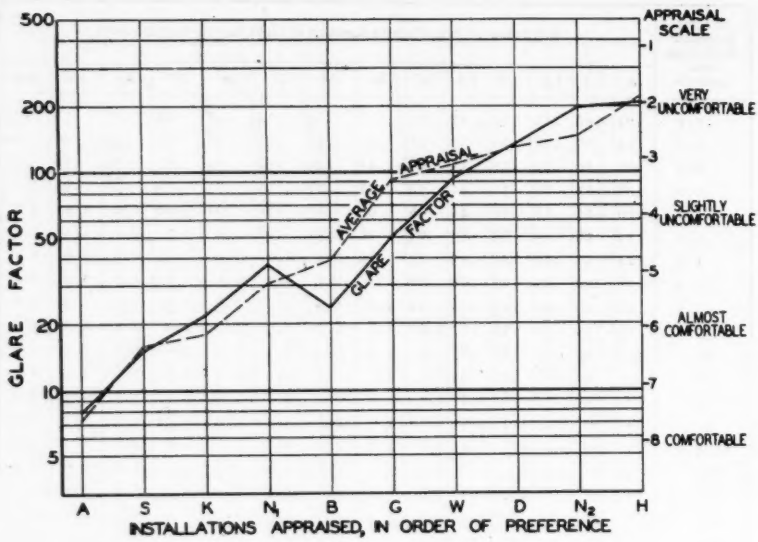


Fig. 13.

contribute but little toward their exploration, and on some of my excursions you may have been unwilling to follow. Nevertheless, can we not agree:—

(1) That further laboratory work should be undertaken on footcandle, or rather footlambert, levels desirable for various tasks, taking into account in each case the physiological cost of seeing.

(2) That we should try to learn more about surround brightness patterns which are satisfying and contribute to ease of seeing; and that practising engineers should endeavour to design lighting systems so as to minimise undesirable specular reflections.

(3) That the proposal concerning a numerical evaluation of direct glare should be subjected to serious and searching criticism. No representations are made that the exponents used in the empirical formula are precise, but even if by trial they are found to be materially in error, is it not worth while to correct them and then proceed to put them into use? To paraphrase Lord Kelvin, numerical evaluation is essential to the understanding and solution of nearly all scientific problems.

TABLE I

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF DIFFUSING GLOBES OF 1500 FOOTLAMBERTS BRIGHTNESS

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet)			
		8	9	10	12
10	10	55	30	22	5
	15	100	60	50	20
	20	140	100	75	35
	30	220	140	110	65
	40	260	170	140	85
	60	340	240	200	120
15	10	70	40	27	7
	15	120	80	60	26
	20	170	110	90	45
	30	250	170	130	80
	40	320	240	170	100
	60	400	300	240	150
20	10	80	50	34	10
	20	190	130	100	55
	30	280	200	150	90
	40	360	260	200	120
	60	480	360	280	180
	80	560	440	350	240
30	10	100	55	38	13
	20	240	150	120	65
	30	340	230	180	120
	40	420	300	250	160
	60	580	440	350	240
	80	700	540	440	300
	100	800	600	500	360
40	10	110	60	40	15
	20	250	170	130	75
	30	360	260	200	140
	40	460	340	260	200
	60	640	480	400	300
	80	760	600	480	360
	100	900	680	560	420

MULTIPLYING FACTORS FOR ABOVE TABLE TO CORRECT FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.2	1.55	1.2	1.5	1.8	1.8	2.3

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.7	.75	.9	**1.0**	1.1	1.15	1.3	1.4

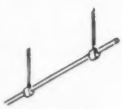
Diffusing Globes. Table I, for example, applies to 16-in. spherical opal globes equipped with 500-watt lamps, and it is used as follows: In the first column find the width of the room (for instance, 20 ft) and in the second column the room length (40 ft), and then go across to the column indicating the mounting height (9 ft). The glare factor for the installation will be 260 as indicated. It will be observed that if the room had been of the same width but 80 ft long, the glare factor would have become 440 or nearly double. It will also be noted that if the mounting height of the units in the 40-ft long room had been increased to 12 ft, the glare factor would have been reduced to 120—that is, more than cut in two. Mounting height is a most important factor in reducing glare.

TABLE II

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF BARE FLUORESCENT LAMPS OF AVERAGE BRIGHTNESS OF 1625 FOOTLAMBERTS

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet) 8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	37	60	30	44	22	26		
	15	45	115	36	90	28	60		
	20	46	170	38	120	30	90		
	30	48	250	41	200	32	140		
	40	50	320	41	250	33	180		
	60	50	440	41	340	35	260		
15	10	50	70	44	50	32	31		
	15	55	130	47	100	35	65		
	20	60	190	50	150	37	100		
	30	60	300	50	240	41	170		
	40	60	400	50	300	43	220		
	60	65	540	55	420	45	300		
20	10	65	80	55	60	40	35	18	15
	20	80	220	65	170	48	110	34	65
	30	80	340	65	260	50	190	38	120
	40	80	440	70	340	55	250	41	160
	60	85	600	70	480	55	360	43	240
	80	85	720	70	580	60	450	43	300
30	10	90	90	70	60	50	36	23	17
	20	115	240	90	190	70	130	50	80
	30	120	380	95	300	75	220	55	140
	40	125	500	100	400	80	300	60	200
	60	130	720	105	580	80	440	65	300
	80	130	880	105	720	85	550	65	400
	100	135	1000	110	840	85	650	65	500
40	10	95	90	75	65	55	36	28	17
	20	135	240	110	190	85	130	60	80
	30	140	380	120	300	95	240	70	140
	40	150	500	120	400	100	300	75	200
	60	150	720	130	600	100	460	80	320
	80	155	900	130	760	105	600	80	420
	100	160	1050	130	900	110	700	80	500



MULTIPLYING FACTORS FOR ABOVE TABLE TO CORRECT FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.2	1.55	1.2	1.5	1.8	1.8	2.3

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.70	.75	.90	**1.00**	1.1	1.15	1.3	1.4

Bare Fluorescent Lamps. Table II gives glare factor data for installations of bare fluorescent lamps, and it will be seen that the values are quite different. For rooms 20 ft by 40 ft with a 9-ft mounting height, two glare factor values—70 and 340—are given. The lesser value applies when the lamps are arranged lengthwise of the room and viewed in that direction; it will be noted that this value is almost the same for all rooms 20 ft or more in length. Comparatively, the glare from lamps placed crosswise is much greater and increases rapidly with the length of the room.

These examples begin to explain some hitherto mystifying observations. For instance, bare lamps may have been recently installed in the manager's private office, and after trying it out for a couple of weeks, he said they were all right and to go ahead and equip the whole general office. After the employees have had the new fixtures for a month, they then express very definite dissatisfaction. Are they just unreasonable or is it perhaps because they have had to face a whole roomful of glaring lights instead of just two or four units as might be visible in the boss's office? In other words, the glare factor is very much worse in the big office.

TABLE III

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF FLUORESCENT FIXTURES HAVING FOUR LAMPS INSIDE A DIFFUSING HALF-CYLINDER 12 IN. DIAM. BY 48 IN. LONG

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	21	50	12	28	10	15		
	15	27	90	18	60	16	38		
	20	30	130	21	80	17	55		
	30	30	170	22	120	19	80		
	40	31	200	23	150	19	110		
	60	32	260	23	180	20	150		
15	10	30	55	21	33	13	19		
	15	35	100	26	80	19	44		
	20	38	140	30	90	24	65		
	30	41	200	32	140	29	110		
	40	42	250	35	180	31	130		
	60	43	320	36	240	34	180		
20	10	38	60	28	35	17	21	12	10
	20	47	150	39	100	31	70	21	47
	30	50	200	42	160	36	120	26	90
	40	55	260	45	200	39	150	28	120
	60	55	350	47	260	42	200	31	170
	80	55	440	47	320	43	260	32	200
30	10	55	65	39	37	26	24	15	11
	20	70	160	55	110	44	80	31	55
	30	75	230	60	180	50	130	39	110
	40	80	300	60	240	50	180	42	150
	60	85	400	65	300	55	250	45	200
	80	85	500	70	380	55	300	46	240
	100	85	560	70	450	55	340	47	280
40	10	65	65	45	40	34	26	17	12
	20	85	160	70	110	60	85	33	60
	40	95	240	75	180	65	140	50	100
	40	95	300	85	240	70	190	50	160
	60	100	440	85	350	75	300	55	220
	80	100	520	85	420	75	350	60	270
	100	105	600	90	480	75	400	60	300

MULTIPLYING FACTORS FOR ABOVE TABLE TO CORRECT FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.2	1.55	1.2	1.5	1.8	1.8	2.3

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.7	.75	.9	**1.0**	1.1	1.15	1.3	1.4

Enclosing Fixtures. Table III gives values for installations of enclosing fixtures in the form of a diffusing half-cylinder surrounding four fluorescent lamps. The average brightness and the glare factors are reduced somewhat in comparison with the bare-lamp installations. It may be pertinent to inquire at this point what is a desirable limit for glare factors in offices and schools. Present experience indicates that glare factors of 15 or less give assurance of freedom from discomfort when the eyes are roving about the horizontal plane from time to time during the working day.

The tables in this article are based on 40 foot-candles of illumination; but at the bottom of each there is a correction value for other levels. For example, for 60-ft-c installations of bare lamps, all glare factors in the table should be multiplied by 1.15. This is largely because more lamps and fixtures are required to produce 60 ft-c and they all add to the discomfort due to glare.

TABLE IV

PROVISIONAL GLARE FACTORS FOR A 40-FT-C INDIRECT INSTALLATION OF SILVERED-BOWL LAMPS IN SHALLOW REFLECTORS. AVERAGE CEILING BRIGHTNESS ABOUT 100 FOOTLAMBERTS

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Ceiling Height (Feet) 9	10	12	14
10	10	3	2	1	1
	15	6	3	2	1
	20	7	5	3	2
	30	8	6	5	2
	40	8	7	6	3
	60	8	7	6	3
15	10	5	3	2	1
	15	8	6	3	2
	20	9	7	5	3
	30	11	8	6	3
	40	12	10	7	4
	60	13	11	7	5
20	10	5	3	2	2
	20	8	7	5	3
	30	11	9	7	5
	40	12	11	7	5
	60	12	11	9	7
	80	13	12	10	7
30	10	6	5	3	2
	20	9	8	6	3
	30	11	10	7	5
	40	12	11	8	6
	60	13	12	10	7
	80	13	13	11	8
	100	14	13	11	8
40	10	6	5	3	2
	20	10	8	6	3
	30	11	10	8	5
	40	12	11	9	6
	60	13	12	10	7
	80	13	13	11	8
	100	14	13	11	8

This table applies for ceiling brightness uniformity of the order of 2.5–1; typical of silvered-bowl lamp installations. If ceiling brightness is distinctly non-uniform, of the order of 5–1, increase the values in the table by multiplying by 1.2. Glare factors for indirect lighting contain no allowance for ceiling beams or ceiling area obscured by luminaires.

MULTIPLYING FACTORS FOR ABOVE TABLE TO CORRECT FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.3	1.8	1.0	1.3	1.8	1.3	1.8

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	20	30	**40**	50	60	80	100
Multiply by:	.40	.65	**1.00**	1.35	1.75	2.70	3.60

Indirect Lighting. Table IV applies to indirect lighting. The light source in this case is the ceiling. The glare factors are much lower than those in Tables I, II, and III (for example, 11 for the 20-ft by 40-ft room with a 10-ft ceiling). If one wishes to obtain a higher level of illumination with indirect lighting, the ceiling brightness must be stepped up. Increasing the brightness has a greater effect on the glare factor than simply adding to the size or number of the light sources. Therefore, glare factors increase rather rapidly with increases in level of indirect illumination. For 60-ft-c, the multiplying factor is 1.75.

TABLE V

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF URC TYPE FLUORESCENT FIXTURES HAVING DENSE DIFFUSING GLASS SIDES AND DEEP LOUVRED BOTTOM

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	5	6	5	6	3	4		
	15	6	9	6	8	4	5		
	20	7	10	6	9	4	6		
	30	8	12	7	11	5	8		
	40	9	14	8	12	6	9		
	60	10	16	8	13	7	11		
15	10	6	7	5	6	3	4		
	15	7	10	6	8	4	6		
	20	8	11	7	9	5	7		
	30	9	14	8	11	6	10		
	40	10	16	9	13	7	12		
	60	12	19	10	16	8	14		
20	10	7	8	6	7	4	5	2	3
	20	10	12	8	11	6	9	5	6
	30	11	15	10	14	8	12	6	9
	40	12	18	11	16	9	14	7	10
	60	13	22	12	19	10	16	8	12
	80	14	25	13	22	10	17	8	14
30	10	7	9	6	7	4	5	2	3
	20	11	15	9	13	7	9	5	7
	30	12	20	11	16	9	12	7	10
	40	14	23	12	30	10	14	8	11
	60	15	26	14	23	12	18	10	13
	80	16	27	15	25	13	20	11	15
	100	17	28	15	26	14	21	12	17
40	10	8	10	7	9	5	6	3	4
	20	11	16	10	14	8	11	6	8
	30	13	22	12	20	10	14	8	10
	40	14	24	13	22	11	16	10	12
	60	16	27	14	25	12	20	11	15
	80	17	28	15	26	13	22	12	18
	100	18	29	16	27	14	23	12	20

MULTIPLYING FACTORS FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.2	1.55	1.2	1.5	1.8	1.8	2.3

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.7	.75	.90	**1.00**	1.1	1.15	1.30	1.4

Louvred-bottom Fixtures. Table V applies to 4-light URC louvred-bottom fixtures with dense glass sides. It will be seen that the glare factors are of the same general order as for indirect lighting and, because of the smaller multiplying factors, are actually less at illuminations of 60 to 100 ft-c or more.

TABLE VI

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF TWO-LAMP 40-WATT DIRECT-INDIRECT ETCHED ALUMINIUM LOUVRED FLUORESCENT FIXTURES

SHIELDING 35 DEG CROSSWISE; 25 DEG LONGITUDINAL

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Mounting Height Above Floor (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	12	8	11	7	8	6		
	15	13	8	13	8	12	7		
	20	13	9	13	8	13	7		
	30	14	9	13	8	13	7		
	40	14	9	13	8	13	7		
	60	14	9	13	8	13	7		
15	10	12	9	11	9	9	8		
	15	13	9	13	9	12	8		
	20	14	9	13	9	13	8		
	30	14	9	14	9	14	8		
	40	14	9	14	9	14	8		
	60	14	9	14	9	14	8		
20	10	12	10	11	9	9	9	6	8
	20	14	10	13	9	13	9	12	8
	30	14	10	14	9	14	9	13	8
	40	14	10	14	9	14	9	13	8
	60	14	10	14	9	14	9	13	9
	80	14	10	14	9	14	9	13	9
30 and 40	20	14	10	13	10	13	9	12	9
	30	14	10	14	10	14	9	13	9
	40	14	10	14	10	14	9	14	9
	60	14	10	14	10	14	9	14	9
	80	14	10	14	10	14	9	14	9
	100	14	10	14	10	14	9	14	9

MULTIPLYING FACTORS FOR OTHER WALL AND CEILING REFLECTANCES AT 40 FT-C

Ceiling	75			50			30	
Walls	50	30	10	50	30	10	30	10
Multiply by:	1.0	1.2	1.55	1.2	1.5	1.8	1.8	2.3

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	40	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.7	.75	.90	1.00	1.1	1.15	1.30	1.4

Aluminium Reflectors. Tables VI and VII each relate to lighting equipment with aluminium reflectors, and louvres which provide similar lengthwise shielding of the lamps. It will be observed that the pendant fixture in Table VI has a somewhat lower glare factor for lengthwise viewing than the flush-mounted troffer in Table VII. The principal contributing cause for this difference is the comparatively darker ceiling (immediate background) resulting from troffer-type lighting.

TABLE VII

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF SINGLE-LAMP 40-WATT ETCHED ALUMINIUM TROFFERS WITH CROSSWISE LOUVRES

SHIELDING 45 DEG CROSSWISE; 25 DEG LONGITUDINAL

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F. (See Note Below)

Room Width	Room Length	Ceiling Height (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	23	6	20	6	14	5		
	15	26	6	25	6	23	5		
	20	26	6	26	6	25	5		
	30	26	6	26	6	26	5		
	40	26	6	26	6	26	5		
	60	26	6	26	6	26	5		
15	10	23	8	20	7	14	6		
	15	26	8	25	7	24	6		
	20	26	8	23	7	25	6		
	30	26	8	26	7	26	6		
	40	26	8	26	7	26	6		
	60	26	8	26	7	26	6		
20	10	23	8	20	8	14	7	8	6
	20	26	8	26	8	25	7	23	6
	30	26	8	26	8	26	7	26	6
	40	26	8	26	8	26	7	26	6
	60	26	8	26	8	26	7	26	6
	80	26	8	26	8	26	7	26	6
30 and 40	20	26	8	26	8	25	8	23	8
	30	26	8	26	8	26	8	26	8
	40	26	8	26	8	26	8	26	8
	60	26	8	26	8	26	8	26	8
	80	26	8	26	8	26	8	26	8
	100	26	8	26	8	26	8	26	8

NOTE: If the average reflectance of the working plane and floor is 30 per cent instead of 15 per cent, decrease the values in above table by 30 per cent. Similarly, if the ceiling has depreciated to one-half of the 75 per cent reflectance, increase the values in the table by 30 per cent.

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.2	.3	.4	.45	.55	.7	.75	.90	**1.00**	1.1	1.15	1.30	1.4

TABLE VIII

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF SINGLE-LAMP 40-WATT FLUORESCENT WHITE TROFFERS WITH CROSSWISE LOUVRES

SHIELDING 45 DEG CROSSWISE; 25 DEG LONGITUDINAL

Ceiling 75 Per Cent R.F.; Walls 50 Per Cent R.F. Working Plane 15 Per Cent R.F. (See Note Below)

Room Width	Room Length	Ceiling Height (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Uni ts Cross-wise
10	10	22	22	20	20	15	17		
	15	24	22	22	21	20	20		
	20	25	22	23	22	21	21		
	30	26	22	25	22	23	21		
	40	26	22	25	22	24	21		
	60	26	22	25	22	24	21		
15	10	22	23	20	21	16	18		
	15	25	24	24	23	22	22		
	20	26	24	25	23	24	22		
	30	27	24	26	23	25	22		
	40	27	24	26	23	26	23		
	60	27	24	26	23	26	23		
20	10	23	23	20	21	16	18	11	15
	20	26	24	26	24	24	23	22	22
	30	27	24	27	24	26	24	24	22
	40	27	24	27	24	27	24	25	22
	60	27	24	27	24	27	24	26	23
	80	27	24	27	24	27	24	26	23
30 and 40	20	26	24	26	24	25	24	22	23
	30	27	24	27	24	26	24	25	24
	40	27	24	27	24	27	24	26	24
	60	27	24	27	24	27	24	27	24
	80	27	24	27	24	27	24	27	24
	100	27	24	27	24	27	24	27	24

NOTE: If the average reflectance of the working plane and floor is 30 per cent instead of 15 per cent, decrease the values in above table by 1/3. Similarly, if the ceiling has depreciated to one-half of the 75 per cent reflectance, increase the values in the table by 1/3.

If two-lamp troffers are installed to obtain 40 ft.-c, multiply the values in the table by 2.

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.20	.30	.40	.45	.55	.70	.75	.90	**1.00**	1.10	1.15	1.30	1.40

TABLE IX

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF RLM 48-IN. FLUORESCENT TWO-LAMP CLOSED-END REFLECTORS

Ceiling Brightness 5 Footlamberts; Wall 30 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	45	65	28	50	18	33		
	15	55	80	40	65	30	55		
	20	60	90	45	75	34	65		
	30	65	95	50	85	40	80		
	40	70	95	55	90	42	80		
	60	75	100	55	90	45	85		
15	10	55	70	38	60	27	46		
	15	65	90	55	80	46	60		
	20	70	105	65	90	50	90		
	30	80	110	70	100	60	95		
	40	80	110	75	105	65	95		
	60	80	110	80	110	70	100		
20	10	60	80	45	65	32	50	19	35
	20	80	110	70	95	60	105	46	65
	30	85	115	75	110	70	105	55	80
	40	85	115	80	110	75	110	60	90
	60	85	115	85	115	80	110	65	95
	80	90	120	85	115	80	110	70	95
30	10	70	85	49	65	35	50	27	42
	20	100	115	80	105	70	115	55	75
	30	105	120	90	115	75	115	65	90
	40	105	120	95	115	80	115	70	105
	60	105	120	100	120	85	120	80	110
	80	110	125	105	120	90	120	85	110
	100	110	125	105	120	90	120	85	115
40	10	80	85	55	70	38	55	29	46
	20	110	115	95	105	85	115	60	75
	30	115	125	110	115	95	120	70	95
	40	115	125	115	120	95	120	80	110
	60	120	125	115	125	100	120	85	115
	80	120	125	115	125	105	120	90	115
	100	120	125	115	125	110	125	90	115

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.10	.15	.20	.30	.45	.55	.65	.85	**1.00**	1.15	1.30	1.60	1.75

Industrial-type Applications. Tables IX and X apply to industrial (RLM) types of reflectors, and are of interest chiefly in affording a basis for comparison of the efficacy of the several shielding schemes. Observations in factories indicate that the fixture shown in Table X provides lighting of reasonably good quality; hence it may be predicted that glare factors in the range of 50 to 75 will probably be found to represent generally acceptable comfort conditions for industrial-type applications. There is in most cases a substantial difference in the type of visual exercise performed by industrial workers as compared with office or drafting-room workers, or school pupils. Accordingly, the limiting value of 15 as previously suggested is no longer applicable. Experience and numerous appraisals will be required to confirm a practical limiting value for factory lighting.

TABLE X

PROVISIONAL GLARE FACTORS FOR 40-FT-C INSTALLATIONS OF RLM 48-IN. FLUORESCENT TWO-LAMP CLOSED-END REFLECTORS, WITH CENTRE BAFFLE GIVING 27 DEG CUTOFF FOR FARTHER LAMP

Ceiling Brightness 5 Footlamberts; Walls 30 Per Cent R.F. Working Plane 15 Per Cent R.F.

Room Width	Room Length	Height Above Floor (Feet)							
		8		9		10		12	
		Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise	Units End-wise	Units Cross-wise
10	10	45	45	30	40	20	35		
	15	60	45	40	40	30	40		
	20	65	45	50	40	35	40		
	30	65	50	55	45	40	40		
	40	70	50	55	45	45	40		
	60	70	50	60	45	45	40		
15	10	50	50	50	45	30	40		
	15	65	55	55	50	45	45		
	20	70	55	65	50	55	45		
	30	75	55	70	50	65	45		
	40	80	60	75	55	65	50		
	60	80	60	80	55	70	50		
20	10	50	55	40	50	30	45	20	35
	20	70	60	65	55	65	50	45	45
	30	75	60	75	55	70	55	55	45
	40	80	65	75	60	75	55	65	45
	60	80	65	80	60	80	60	65	50
	80	80	65	80	65	80	60	70	50
30	10	50	60	40	55	30	50	25	40
	20	70	65	65	60	65	55	50	50
	30	75	65	75	60	65	60	65	55
	40	80	65	75	60	70	60	70	55
	60	80	70	80	65	76	60	75	55
	80	80	75	80	65	80	65	80	60
	100	80	75	80	65	80	65	80	60
40	10	50	60	40	55	30	50	25	45
	20	70	65	65	65	65	60	50	55
	30	75	65	75	65	65	60	65	60
	40	80	70	75	65	70	60	70	60
	60	80	75	80	70	75	60	75	60
	80	80	80	80	70	80	65	80	60
	100	80	85	80	75	80	65	80	60

MULTIPLYING FACTORS FOR OTHER FOOT-CANDLE LEVELS

Foot-candles	1	2	3	5	10	15	20	30	**40**	50	60	80	100
Multiply by:	.10	.15	.20	.30	.45	.55	.65	.85	**1.00**	1.15	1.30	1.60	1.75

THE ANNUAL GENERAL MEETING

The annual general meeting of the Illuminating Engineering Society took place at the Royal Hall, Ripon-road, Harrogate, Yorkshire, at 2.30 p.m. on Thursday, June 17, 1948.

The Secretary having read the notice convening the meeting and the statement of the auditors for the past year, it was agreed that the minutes of the last meeting be taken as read and approved.

The President presented the Report of the Council for the year 1947, and the Hon. Treasurer dealt with the statement of accounts for that period, explaining that a further small amount had been invested for future developments.

Adoption of Report and Accounts

The following resolution was then put to the meeting by Mr. W. G. Thompson and seconded by Mr. N. D. Houston:—

> That the Report of the Council and the accounts of the Illuminating Engineering Society for the period January 1,1947, to December 31, 1947, be hereby adopted, and that a vote of thanks be extended to the President, Council and Officers for their efforts on behalf of the Society during the past year.

On the resolution being put to the meeting the Report was declared carried unanimously.

The President, on behalf of the Officers and Council, expressed his appreciation of the vote of thanks. He also expressed his thanks to the Officers and Council and to the headquarters staff for the support they had given him during his term of office.

On the proposal of Mr. J. Stewart, seconded by Mr. G. E. L. Comrie, Messrs. Robert Ward and Co. were unanimously re-elected as auditors of the Society for the year ending December 31, 1948.

Election of Officers and Council

The President reported that there had been no independent nominations and the Council's nominations for Officers and members of Council therefore stood. Those elected were as follows:—

President: Mr. J. M. Waldram.

Vice-Presidents: Dr. E. C. Walton, Mr. E. W. Murray, Dr. J. N. Aldington.

Hon. Treasurer: Mr. J. G. Holmes.

Hon. Secretary: Mr. H. C. Weston.

Hon. Editor of Transactions: Mr. W. R. Stevens.

Members of Council: Mr. A. D. S. Atkinson, Mr. H. S. Barlow, Mr. G. H. Giles, Dr. H. F. Gillbe, Mr. E. C. Lennox, Mr. L. C. Rettig, Mr. W. T. F. Souter, Mr. S. G. Turner.

Other Business

The President then announced that the Register of Lighting Engineers (I.E.S.), which had been approved at the last annual general meeting, had come into operation in February, 1948, and that the inclusion of the names of a number of members had already been approved by the Council.

The President also recalled that since the last annual general meeting the Society had suffered the loss of one of its oldest members, Mr. A. P. Trotter. The President reviewed the work of Mr. Trotter in the field of illuminating engineering, and said that as a tribute to his memory the Council had decided to institute a Trotter Memorial Lecture, which would be given at intervals of approximately two years. An appeal would shortly be made to members to raise a fund towards the cost of these lectures, and the President emphasised that though members were asked to contribute as generously as possible, the main intention was that as many members as

possible should associate themselves with the scheme.

In reply to a question regarding the attendance of members of Council at Council meetings, the President said that there must inevitably be occasions when members were unable to attend meetings, and he assured the meeting that there was no lack of activity on the part of Council members.

With regard to the absence of independent nominations for members of Council, the President outlined the procedure for nominations, and explained that after the Council had considered and voted on the nominations of the Council members themselves (including Centres representatives) the list of their nominees was published in good time for any group of ten members to make an independent nomination in accordance with the Articles of the Society. In reply to a question regarding the representation of Centres on the Council it was pointed out that over 60 per cent. of the members of Council for the forthcoming session would be from the Centres.

This terminated the formal business.

Some Frontiers of the Lighting Art

Dr. Walsh then introduced Mr. Ward Harrison, a Past-President of the Illuminating Engineering Society of America, and called upon him to present his address. Mr. Ward Harrison opened his address by expressing, on behalf of his colleagues in the American I.E.S. and on behalf of himself, the honour they felt on the invitation to address the British I.E.S. He also paid tribute to the invaluable contributions to the development of fluorescent lamps which had been made in this country.

He then dealt with the work which lay before the lighting engineer, and mentioned a number of fields in which further research was required. He said it would be impossible within the scope of his address to enlarge on more than a few of these, and he confined his further remarks to desirable levels of illumination, suitable brightness distribution surrounding the visual task, and ocular comfort when the eyes are raised from the work.

Mr. W. J. Jones, in proposing a vote of thanks to Mr. Ward Harrison, said he felt greatly privileged at being called upon to do this, first, because Mr. Ward Harrison was a distinguished representative of the American Illuminating Engineering Society, and, secondly, because he had been closely associated with the art and science of illuminating engineering for so many years.

Mr. Jones also expressed the thanks of the lighting research laboratories in this country for the graceful way in which Mr. Harrison had referred to British developments in fluorescent lamps, and said how glad they were to have been associated with their colleagues in the United States on this subject.

Mr. Jones then proposed that a vote of thanks be accorded to Mr. Ward Harrison both for his invaluable contributions to illuminating engineering and for the address which he had just presented.

Dr. E. C. Walton, in seconding the vote of thanks, said he would like to convey to Mr. Ward Harrison how greatly the Society appreciated his presence at this meeting and with what great pleasure they had listened to his address. Mr. Ward Harrison, he said, had given a really admirable survey of the present position in the field of illuminating engineering and had set out very clearly the problems which confronted the lighting engineer. He said he was sure that all members would feel most indebted to Mr. Harrison for the address he had give, and he therefore had the greatest pleasure in seconding the vote of thanks proposed by Mr. W. J. Jones.

The vote of thanks was passed with enthusiasm, and the meeting terminated.

SESSION 1947—1948

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